

## COATING COMPOSITION FOR USE IN SLIDING PARTS

## BACKGROUND OF THE INVENTION

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The present invention relates to a coating composition for use in sliding parts and a process of preparing the same.

Japanese Laid-Open Patent Publication No. 2001-11372, 10 for example, discloses a coating composition for use in sliding parts that is prepared by mixing polyamide-imide, polytetrafluoroethylene, and alumina powder.

This type of coating composition for use in sliding 15 parts is applied onto a substrate and then heated to form a sliding film on the substrate. The formed sliding film has good wear resistance and seizure resistance. For example, when employing a sliding film formed of this coating composition for use in sliding parts for the outer surface of 20 skirts of a piston provided in an internal combustion engine, the piston suitably slides through a cylinder bore in the internal combustion engine and produces effects of high rotation, high compression ratio, etc. of the internal combustion engine.

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However, in the sliding film formed of the above 30 coating composition for use in sliding parts, there have still been demands that it have further improved seizure resistance, though it certainly has good wear resistance even under severer conditions.

## SUMMARY OF THE INVENTION

Accordingly, the object of this invention is to provide 35 a coating composition for use in sliding parts that is

capable of forming a sliding film having good wear resistance and seizure resistance and a process of preparing the same.

To accomplish the above object, the present invention  
5 provides a coating composition for use in sliding parts. The composition is obtained by mixing a binder resin, a solid lubricant, titanium oxide powder, and a coupling agent.

Other aspects and advantages of the invention will  
10 become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

#### BRIEF DESCRIPTION OF THE DRAWINGS

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The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

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FIG. 1 is a perspective view showing the main part of a journal bearing tester; and

FIG. 2 is a perspective view showing the main part of a thrust type tester.

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#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

One embodiment of the present invention will now be described.

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The coating composition for use in sliding parts in accordance with this invention is first applied onto a substrate and then heated to form a sliding film on the substrate. The formed sliding film contains a solid lubricant,  
35 titanium oxide powder and a coupling agent in its cured

binder resin. The solid lubricant and the titanium oxide are dispersed in the binder resin. The solid lubricant in the sliding film ensures the seizure resistance of the substrate and the mating material of the substrate, like conventional 5 sliding films. The titanium oxide powder in the sliding film probably supports the loads acting between the substrate and the mating material. The coupling agent in the sliding film probably binds the solid lubricant and the titanium oxide powder firmly to the binder resin, and at the same time, 10 bonds the sliding film firmly to the substrate. According to the test results obtained by the inventors, sliding films using alumina powder, silica powder or silicon carbide powder, all of which are inorganic particles just like titanium oxide powder, have good wear resistance, but not good seizure 15 resistance. In contrast, sliding films using titanium oxide powder has both good wear resistance and seizure resistance. The marked improvement in wear resistance in these films may be attributed to the fact that titanium oxide powder has excellent dispersability in the binder resin, and therefore, 20 produces excellent effects of providing the sliding films with surface smoothness and preventing the solid lubricant from dropping out of the sliding films. As the titanium oxide, any one of anatase, rutile and brookite types of titanium dioxide can be employed. However, of the above types, rutile 25 titanium dioxide is optimally used, taking into consideration the deterioration of the binder resin due to photocatalytic action and the cost.

As the binder resin, is employed one having excellent 30 heat resistance, such as polyimide resin composed of polyamide-imide, polyimide, etc., epoxy resin or phenol resin. Of the above resins, polyamide-imide is optimally used, taking into consideration the cost and the properties as a binder resin. The resins in the uncured state are used in the 35 coating composition for use in sliding parts of this

invention.

As the solid lubricant, is employed polytetrafluoroethylene (PTFE), ethylene tetrafluoroethylene (ETFE), tetrafluoroethylene-hexafluoropropylene copolymer (FEP), molybdenum disulfide or graphite.

Preferably the average primary particle diameter of titanium oxide powder is 1  $\mu\text{m}$  or less. Titanium oxide powder having an average primary particle diameter of 1  $\mu\text{m}$  or less has excellent dispersability in the binder resin and produces large effect of providing the sliding film with surface smoothness and preventing the solid lubricant from dropping out of the film. Further, titanium oxide powder having an average primary particle diameter of 1  $\mu\text{m}$  or less makes it possible to constitute an optimum sliding film for a small gap between a first sliding surface of a first member and a second sliding surface of a second member that slide upon each other through the small gap.

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In the sliding film formed of the coating composition for use in sliding parts, the content of solid lubricant in binder resin is preferably in the range between 15% by mass and 100% by mass, inclusive, and more preferably in the range between 30% by mass and 80% by mass, inclusive. If the content of solid lubricant in binder resin is less than 15% by mass, the seizure resistance of the sliding film becomes poor, whereas if the content of solid lubricant in binder resin is more than 100% by mass, the improvement in the seizure resistance of the sliding film becomes small and the solid lubricant becomes apt to drop out of the film, resulting in increased wear depth of the sliding film.

35 In the sliding film formed of the coating composition for use in sliding parts, the content of titanium oxide

powder in binder resin is preferably in the range between 5% by mass and 35% by mass, inclusive, and more preferably in the range between 10% by mass and 20% by mass, inclusive. If the content of titanium oxide powder in binder resin is less than 5% by mass, the effect of decreasing the wear depth of the sliding film becomes insufficient, whereas if the content of titanium oxide powder in binder resin is more than 35% by mass, the effect of decreasing the wear depth of the sliding film becomes small.

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Further, in the sliding film formed of the coating composition for use in sliding parts, the content of coupling agent in binder resin is preferably in the range between 0.1% by mass and 10% by mass, inclusive, and more preferably in the range between 2% by mass and 8% by mass, inclusive. If the content of coupling agent in binder resin is less than 0.1% by mass, the seizure resistance of the sliding film becomes insufficient, whereas if the content of coupling agent in binder resin is more than 10%, the effect of improving the seizure resistance of the sliding film becomes small.

As the coupling agent, is employed a silane coupling agent, a titanate coupling agent, or an aluminate coupling agent. According to the test results obtained by the inventors, it is preferable to employ a silane coupling agent. Silane coupling agents usable include: for example, vinyltrichlorosilane, vinyltrimethoxysilane, vinyltriethoxysilane, 2-(3,4-epoxycyclohexyl)ethyl trimethoxysilane, 3-glycidoxypropyl trimethoxysilane, 3-glycidoxypropyl methyldiethoxysilane, 3-glycidoxypropyl triethoxysilane, p-styryltrimethoxysilane, 3-methacryloxypropyl methyl dimethoxysilane, 3-methacryloxypropyl trimethoxysilane, 3-methacryloxypropyl methyl diethoxysilane, 3-methacryloxypropyl triethoxysilane,

3-acryloxypropyl trimethoxysilane, N-2(aminoethyl)3-aminopropyl methyl dimethoxysilane, N-2(aminoethyl)3-aminopropyl trimethoxysilane, N-2(aminoethyl)3-aminopropyl triethoxysilane, 3-aminopropyl trimethoxysilane, 3-aminopropyl triethoxysilane, 3-triethoxysilyl-N-(1,3-dimethyl-butylidene)propylamine, N-phenyl-3-aminopropyl trimethoxysilane, hydrochloride of N-(vinylbenzyl)-2-aminoethyl-3-aminopropyl trimethoxysilane, special aminosilane, 3-ureidopropyl triethoxysilane, 3-chloropropyl trimethoxysilane, 3-mercaptopropyl methyldimethoxysilane, 3-mercaptopropyl trimethoxysilane, bis(triethoxysilylpropyl)tetrasulfide, and 3-isocyanatopropyl triethoxysilane. When polyamide-imide is employed as binder resin, it is preferable to employ, as a silane coupling agent, 2-(3,4-epoxycyclohexyl)ethyl trimethoxysilane, 3-triethoxysilyl-N-(1,3-dimethyl-butylidene)propylamine, N-phenyl-3-aminopropyl trimethoxysilane, 3-ureidopropyl triethoxysilane and/or 3-isocyanatopropyl triethoxysilane. It is particularly preferable to employ 2-(3,4-epoxycyclohexyl)ethyl trimethoxysilane, which has an epoxy group as a functional group, 3-glycidoxypropyl trimethoxysilane, 3-glycidoxypropyl methyldiethoxysilane, and 3-glycidoxypropyl triethoxysilane. These four agents are also excellent in storage stability.

To ascertain the effect of the coating composition for use in sliding parts of this invention, the following physical property tests were performed. The physical property tests will be described below with the aid of FIGS. 1 and 2.

First, the following ingredients were prepared.

Solid lubricant: PTFE powder (average primary particle diameter 0.3  $\mu\text{m}$ ), molybdenum disulfide (average primary particle diameter 1  $\mu\text{m}$ ), graphite (average primary particle diameter 5  $\mu\text{m}$ )

Inorganic particles: rutile titanium oxide powder  
(average primary particle diameter 0.3 µm), silicon carbide  
powder (average primary particle diameter 0.3 µm), silica  
5 powder (average primary particle diameter 0.3 µm)

Silane coupling agent: 2-(3,4-epoxycyclohexyl)ethyl  
trimethoxysilane, 3-glycidoxypropyl trimethoxysilane, 3-  
glycidoxypropyl methyldiethoxysilane, 3-glycidoxypropyl  
10 triethoxysilane, 3-triethoxysilyl-N-(1,3-dimethyl-  
butylidene)propylamine, N-phenyl-3-aminopropyl  
trimethoxysilane, 3-ureidopropyl triethoxysilane, 3-  
isocyanatopropyl triethoxysilane

15 Binder resin: polyamide-imide (PAI) resin varnish (PAI  
resin 30% by mass, solvent (n-methyl-2-pyrrolidone 56% by  
mass, xylene 14% by mass) 70% by mass)

PAI resin varnish was blended with a solid lubricant  
20 (PTFE, MoS<sub>2</sub>, etc.), titanium oxide powder and a coupling  
agent, fully stirred and passed through a triple roll mill to  
prepare a coating composition for use in sliding parts. The  
coating composition for use in sliding parts was optionally  
diluted with n-methyl-2-pyrrolidone or xylene, as a solvent,  
25 or the mixed solvent thereof depending on the types of  
coating methods employed (spray coating, roll coating, etc.)  
for the purpose of adjustment of viscosity, solid material  
concentration, etc. The coating composition for use in  
sliding parts may also be prepared in such a manner as to  
30 first blend a solid lubricant and titanium oxide powder with  
a coupling agent to prepare a treated powder and then mix the  
treated powder with PAI resin varnish. Thus, it is possible  
that the solid lubricant and the titanium oxide powder are  
suitably dispersed in the PAI resin varnish, hard to  
35 maldistribute in a sliding film formed of the coating

composition for use in sliding parts and bound securely to the binder resin via the coupling agent.

Then, degreased ingot of aluminum alloy A 390 was prepared and a plurality of substrates 1, as first members, with its section perpendicular to the axis having C-like shape and its length 20 mm were formed as shown in FIG. 1. Of the substrates, two were selected and combined so that they were allowed to face each other to form a bush 20 mm in inside diameter. Coating compositions for use in sliding parts having been prepared so that sliding films C1 to C37 had the respective compositions shown in Table 1 to Table 4 were coated on the inside surface 1a of the respective substrates 1 by air spraying to form coating films 25  $\mu\text{m}$  thick. Table 1 to Table 4 also show the amount % by mass of each solid lubricant, inorganic particles or silane coupling agent per 100 mass % of PAI resin. Coating can also be carried out by roll coat transferring, instead of air spraying. The substrates 1 each having a coating formed on their inside surface were heated at 200°C for 60 minutes under the atmospheric conditions to cure the PAI resin. Thus sliding films C1 to C37 were applied onto the respective substrates 1.

Table 1

(mass %)	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
PAI resin (as an active ingredient)	65	65	65	65	65	65	65	65	65	65
PTFE powder	35	30	25	15	34	33	32	28	23	13
molybdenum disulfide	-	-	-	-	-	-	-	-	-	-
graphite	-	-	-	-	-	-	-	-	-	-
mass % of solid lubricant per 100 mass % of PAI resin	53.8	46.2	38.5	23.1	52.3	50.1	49.2	43.1	35.4	20.0
Inorganic particle	titanium oxide powder	-	5	10	20	-	-	-	5	10
silicon carbide powder	-	-	-	-	-	-	-	-	-	-
silica powder	-	-	-	-	-	-	-	-	-	-
mass % of inorganic particle per 100 mass % of PAI resin	0	7.7	15.4	30.8	0	0	0	7.7	15.4	30.8
Silane coupling agent	2-(3,4-epoxycyclohexyl)ethyl trimethoxysilane	-	-	-	1	2	3	2	2	2
	3-triethoxysilyl-N-(1,3-dimethylbutyldiene)propylamine	-	-	-	-	-	-	-	-	-
	N-phenyl-3-aminopropyl trimethoxysilane	-	-	-	-	-	-	-	-	-
	3-ureidopropyl triethoxysilane	-	-	-	-	-	-	-	-	-
	3-isocyanatopropyl triethoxysilane	-	-	-	-	-	-	-	-	-
mass % of silane coupling agent per 100 mass % of PAI resin	0	0	0	1.5	3.1	4.6	3.1	3.1	3.1	3.1

Table 2

(mass %)	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
PAI resin (as an active ingredient)	65	65	58	50	65	65	65	65	65	65
PTFE powder	24	23	22	30	38	23	23	23	23	-
molybdenum disulfide	-	-	-	-	-	-	-	-	-	25
graphite	-	-	-	-	-	-	-	-	-	10
mass % of solid lubricant per 100 mass % of PAI resin	36.9	35.4	33.8	51.7	76.0	35.4	35.4	35.4	35.4	53.8
titanium oxide powder	10	10	10	10	10	10	10	10	10	-
Inorganic silicon carbide powder	-	-	-	-	-	-	-	-	-	-
silica powder	-	-	-	-	-	-	-	-	-	-
mass % of inorganic particle per 100 mass % of PAI resin	15.4	15.4	15.4	17.2	20.0	15.4	15.4	15.4	15.4	0
2-(3,4-epoxycyclohexyl)ethyl trimethoxysilane	1	2	3	2	2	-	-	-	-	-
3-triethoxysilyl-N-(1,3-dimethylbutyldiene)propylamine	-	-	-	-	2	-	-	-	-	-
Silane coupling N-phenyl-3-aminopropyl agent trimethoxysilane	-	-	-	-	-	2	-	-	-	-
3-ureidopropyl triethoxysilane	-	-	-	-	-	-	2	-	-	-
3-isocyanatopropyl triethoxysilane	-	-	-	-	-	-	-	-	2	-
mass % of silane coupling agent per 100 mass % of PAI resin	1.5	3.1	4.6	3.4	4.0	3.1	3.1	3.1	3.1	0

Table 3

(mass %)	C21	C22	C23	C24	C25	C26	C27	C28	C29	C30
PAI resin (as an active ingredient)	95	90	80	70	50	80	80	70	70	75
Solid lubricant	PTFE powder	-	-	-	-	-	-	-	20	20
	molybdenum disulfide	-	-	-	-	-	-	20	-	-
	graphite	-	-	-	-	-	-	-	10	-
mass % of solid lubricant per 100	0	0	0	0	0	0	0	42.9	28.9	26.7
mass % of PAI resin										
Inorganic particle	titanium oxide powder	5	10	20	30	50	-	-	10	-
	silicon carbide powder	-	-	-	-	20	-	-	-	-
	silica powder	-	-	-	-	-	20	-	-	-
mass % of inorganic particle per 100	5.3	11.1	25.0	42.9	100.0	25.0	25.0	0	14.3	0
mass % of PAI resin										
Silane coupling agent	2-(3,4-epoxycyclohexyl)ethyl trimethoxysilane	-	-	-	-	-	-	-	-	5
mass % of silane coupling agent per 100	0	0	0	0	0	0	0	0	0	6.7
mass % of PAI resin										

Table 4

(mass %)	C31	C32	C33	C34	C35	C36	C37
PAI resin (as an active ingredient)	65	65	65	65	65	65	80
PTFE powder	20	24.9	21	23	23	23	20
molybdenum disulfide	-	-	-	-	-	-	-
graphite	-	-	-	-	-	-	-
mass % of solid lubricant per 100 mass % of PAI resin	30.1	38.3	32.3	35.4	35.4	35.4	25.0
Inorganic particle	titanium oxide powder	10	10	10	10	10	-
	silicon carbide powder	-	-	-	-	-	-
	silica powder	-	-	-	-	-	-
mass % of inorganic particle per 100 mass % of PAI resin	15.4	15.4	15.4	15.4	15.4	15.4	0
Silane coupling agent	2-(3,4-epoxycyclohexyl)ethyltrimethoxysilane	5	0.1	4	-	-	-
	3-glycidoxypropyltrimethoxysilane	-	-	2	-	-	-
	3-glycidoxypropylmethyldiethoxysilane	-	-	-	2	-	-
	3-glycidoxypropyltriethoxysilane	-	-	-	-	2	-
mass % of silane coupling agent per 100 mass % of PAI resin	7.7	0.2	6.2	3.1	3.1	3.1	0

Further, a plurality of substrates 3, as first members, were prepared by cutting the above described ingot to 30 mm long, 30 mm wide and 5 mm thick, as shown in FIG. 2. The surfaces 3a of the substrates 3 were coated, by air spraying, 5 with the respective coating compositions for use in sliding parts C1 to C37 that had been prepared to have the compositions shown in Table 1 to Table 4 to form coating films 25  $\mu\text{m}$  thick. Coating can also be carried out by roll coat transferring, instead of air spraying. The substrates 3 10 each having a coating formed on their inside surface were heated at 200°C for 60 minutes under the atmospheric conditions to cure the PAI resin. Thus sliding films C1 to C37 were applied onto the respective substrates 3.

15 The surface roughness ( $R_z$ ) of each of the sliding films C21 to C28 was measured.

The wear depth ( $\mu\text{m}$ ) was obtained with a journal bearing tester shown in FIG. 1. In the wear depth measurement with a 20 journal bearing tester, first a shaft 2, as a second member, which was made up of carbon steel (S55C) and 20 mm in diameter was inserted into and passed through a bush consisting of a pair of substrates 1. And the measurement was carried out while setting a load from the bush at 1000 N, 25 testing time at 1 hour and the number of revolutions of the shaft 2 against the bush at 5000 rpm (5.2 m/sec) and constantly supplying lubricating oil between the bush and the shaft 2.

30 Further, the seizure specific pressure (MPa) was obtained with a thrust-type tester shown in FIG. 2. In the seizure specific pressure measurement with a thrust-type tester, a cylindrical member 4, as a second member, which was made up of spring steel (SUJ2) was rotated on the surface 3a 35 (a first sliding surface) of each substrate 3. The load at a

time when seizure occurred between the surface 3a of each substrate 3 and the surface (a second sliding surface) of the cylindrical member 4 that was opposite to the surface 3a was obtained while rotating the cylindrical member 4 at a 5 rotational speed to increase 1.2 m/sec on a fixed cycle (1 MPa/2 mins), that is, to increase the load applied from the cylindrical member 4 to the substrate 3. The kinetic coefficient of friction was also measured for each substrate 3 right after and 100 hours after starting the test under the 10 conditions: a sliding speed of 1.2 m/sec and a specific pressure of 9.8 MPa. For the sliding films of C1 to C20 and C29 to C37, the kinetic coefficient of friction was not measured. The results are shown in Table 5 to Table 7.

Table 5

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Wear depth ( $\mu\text{m}$ )	24.0	22.1	16.5	15.5	21.8	14.6	15.2	9.5	6.8	7.7
Seizure contact pressure (MPa)	10	12	16	13	13	14	16	23	25 or more	25 or more

	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
Wear depth ( $\mu\text{m}$ )	7.8	5.9	6.5	5.8	6.2	7.2	6.9	8.1	7.2	exposure of substrate
Seizure contact pressure (MPa)	24	25 or more	25 or more	22	24	24	25 or more	22	24	25 or more

Table 6

	C21	C22	C23	C24	C25	C26	C27	C28	C29	C30
Surface roughness (Rz)	0.21	0.19	0.20	0.20	0.31	0.32	0.36	1.98	-	-
Kinetic coefficient of friction	Just after starting test	0.024	0.023	0.021	0.023	0.027	0.031	0.038	0.052	-
	100 hours after starting test	0.021	0.018	0.017	0.020	0.025	0.027	0.032	0.048	-
Wear depth (μm)	4.0	3.1	2.8	2.6	5.2	5.1	6.3	19.0	4.5	4.3
Seizure contact pressure (MPa)	21	22	25 or more	22	18	20	18	25 or more	25 or more	22

Table 7

	C31	C32	C33	C34	C35	C36	C37
Surface roughness (Rz)	-	-	-	-	-	-	-
just after starting test	-	-	-	-	-	-	-
Kinetic coefficient of friction							
100 hours after starting test	-	-	-	-	-	-	-
Wear depth ( $\mu\text{m}$ )	2.1	7.5	6.6	5.7	6.2	6.3	10.3
Seizure contact pressure (MPa)	25 or more	23	24	25 or more	24	24	20

The data on the sliding films C1 to C4 and C20 shown in Table 5 and C37 shown in Table 7 indicate that when a sliding film is formed of binder resin which contains a solid lubricant and in which part of the solid lubricant is replaced with titanium oxide powder, it has not satisfactorily improved wear resistance and seizure resistance. In addition, the data on the sliding films C1, C5 to C7, and C20 shown in Table 5 and C37 shown in Table 7 indicate that when a sliding film is formed of binder resin which contains solid lubricant and in which part of the solid lubricant is replaced with a silane coupling agent, it has not satisfactorily improved wear resistance and seizure resistance.

The data on the sliding films C1, C8 to C10, and C20 shown in Table 5 and C37 shown in Table 7 indicate that when a sliding film is formed of binder resin which contains solid lubricant, titanium oxide powder and a silane coupling agent, it has particularly improved wear resistance and seizure resistance.

The data on the sliding films C11 to C19 shown in Table 5, C30 shown in Table 6, and C31 to C36 in Table 7 indicate that when a sliding film is formed of binder resin which contains solid lubricant, titanium oxide powder and a silane coupling agent, if the percentage of the silane coupling agent to the PAI resin is in the range between 0.1% by mass and 10% by mass, inclusive, centered at 3% by mass, it has particularly improved wear resistance and seizure resistance. On the other hand, the data on the sliding films C14 and C15 shown in Table 5 indicate that even if the amount of the binder resin is decreased compared with that of the sliding films C12 and C13, as long as films contain titanium oxide powder and a silane coupling agent, their wear resistance is excellent and their seizure resistance does not deteriorate.

very much.

The data on the sliding films C9 and C16 to C19 shown in Table 5 and C34 to C36 shown in Table 7 indicate that as long as the silane coupling agent is 2-(3,4-epoxycyclohexyl)ethyl trimethoxysilane, 3-triethoxysilyl-N-(1,3-dimethyl-butylidene)propylamine, N-phenyl-3-aminopropyl trimethoxysilane, 3-ureidopropyl triethoxysilane, 3-isocyanatopropyl triethoxysilane, 3-glycidoxypipropyl trimethoxysilane, 3-glycidoxypipropyl methyldiethoxysilane or 3-glycidoxypipropyl triethoxysilane, sliding films all have excellent wear resistance and seizure resistance. Particularly those using 2-(3,4-epoxycyclohexyl)ethyl trimethoxysilane, 3-glycidoxypipropyl trimethoxysilane, 3-glycidoxypipropyl methyldiethoxysilane or 3-glycidoxypipropyl triethoxysilane are preferable in terms of their storage stability.

The data on the sliding film C20 shown in Table 5, C21 to C25 shown in Table 6, and C37 shown in Table 7 indicate that the sliding films formed of coating composition for use in sliding parts that contains titanium oxide powder is more excellent in wear resistance than those formed of coating composition for use in sliding parts that does not contain titanium oxide powder. The sliding films in which the content of titanium oxide powder in PAI resin is more than 35% by mass are less effective in decreasing depth of wear.

The data on the sliding film C20 shown in Table 5, C23, C26 and C27 shown in Table 6, and C37 shown in Table 7 indicate that the sliding films formed of coating compositions for use in sliding parts that contains inorganic particles is more excellent in wear resistance than those formed of coating compositions for use in sliding parts that do not contain inorganic particles; however, the sliding

films using silicon carbide powder or silica powder as inorganic particles are good in wear resistance to some extent, but poor in seizure resistance. The same is true for the sliding films using alumina powder. In contrast, the 5 sliding films using titanium oxide powder are good in both wear resistance and seizure resistance.

Further, in the sliding films using titanium oxide powder, their surface roughness is smaller and their surface 10 smoothness is more excellent than that of the sliding films using silicon carbide powder or silica powder. The data on the sliding films C28 and C29 shown in Table 6 indicate that the sliding films using titanium oxide powder exert more excellent effect of preventing solid lubricant from dropping 15 out of the films and have more markedly improved wear resistance than sliding films using an increased amount of solid lubricant. This is because titanium oxide powder has excellent dispersability in binder resin. Although titanium oxide powder having an average primary particle diameter of 20 0.3  $\mu\text{m}$  is used in the tests, even if titanium oxide powder has an average primary particle diameter of less than 0.3  $\mu\text{m}$  or more than 0.3  $\mu\text{m}$ , as long as it has an average diameter of 1  $\mu\text{m}$  or less, the titanium oxide powder has excellent 25 dispersability in the binder resin and exert excellent effect of preventing solid lubricant from dropping out of the films, whereby it can provide markedly improved wear resistance.

The data on the sliding film C30 shown in Table 6 and C31 shown in Table 7 show that the sliding films using a 30 silane coupling agent are superior in wear resistance to those using no silane coupling agent. This may be because a silane coupling agent serves to bind solid lubricant and titanium oxide powder firmly to binder resin and bond the same firmly to the substrate.

As described so far, sliding films made up of the coating composition for use in sliding parts of this embodiment have excellent wear resistance and seizure resistance even under severer conditions.

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The present examples and embodiments are to be considered as illustrative and not restrictive and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalence of the 10 appended claims.